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IMPLEMENTATION OF A MATHEMATICAL COMPONENT IN THE DEVICE DEVELOPMENT FOR OPERATIONAL CONTROL OF THE DUMP TRUCK

Purpose. To create a device for weighing mining rock loaded into the body of a dump truck after each cycle of its excavation. To develop a mathematical block for calculating the net mass of the rock without taking into account extraneous factors affecting the accuracy of the obtained result. To provide operational control of the nominal load of the dump truck by the driver and excavator operator.

Methodology. The methodological basis for solving the task is a comprehensive approach which includes electronic modeling of technical processes, methods of mathematical statistics, analysis of results in a mathematical package and their applied application.

Findings. A functional and principled electrical diagram of the device for weighing the mining rock loaded into the body of a dump truck and transferring the final information to this excavator has been compiled. A mathematical block of the device was created, capable of memorizing the signals received from the primary information sensors before weighing, and subtracting them from the signals received from these sensors after each weighing cycle. As sensors of primary information, it is proposed to use selsyns, which are part of the transformer mode, which are mass-produced by the industry, reliable in operation and easy to maintain.

Originality. The proposed device is made at the level of the invention; its priority is determined by the constructive development and technical solution. Namely, the device is equipped with a multistable memory transformer, to the erasing winding of which a tachogenerator (or tachometer generator) is connected through an amplifier, a chain of series-connected trigger, multivibrator waiting and key, whose output is connected to the recording winding of the multistable memory transformer, as well as the transformer connected to the input winding of the multistable memory transformer. Moreover, the storage capacitor is connected to one of the key inputs, and the input windings of the transformer are connected to the weight sensor.

Practical value. The use of the presented device allows for operational control of the nominal load of the dump truck, objective accounting of transported cargo and realized labor costs, as well as for applying optimal maintenance of cargo and transport works in quarries. In the future, this device will form the basis of a radio telemetry system for dispatching the operation of dump trucks.

Keywords: *dump truck, excavator, mathematical block, pulses, voltage, weight sensors, rock mass*

Introduction. The use of heavy-duty dump trucks in modern quarries ensures the transportation of significant volumes of rock from excavator blocks located on different horizons to their destinations. At the same time, the control of their loading is carried out visually by the excavator operator on the basis of experience. The lack of objective information about the weight of the rock loaded into the dump truck during each cycle of its excavation determines the probability of exceeding its carrying capacity. The operation of an overloaded dump truck on quarry roads certainly affects the reliability of its individual components. In addition, it is difficult to optimize the management of freight and transport operations without operational accounting of the volumes of mined rock for each excavator, dump truck and in general for the quarry. The problem of ensuring the nominal load of the dump truck and obtaining the necessary information in the control room can really be solved by the introduction of an automatic device for weighing the rock during its extraction.

The difficulties of creating such a device are due to the technical conditions that apply to it, namely:

- the accuracy of weighing must be within the limits accepted for this type of work;
- its reliable operation in mining conditions;
- sensors of primary information must steadily issue electrical signals in accordance with the weight of the rock loaded into the body of the dump truck. At the same time, it is extremely important that the specified sensors are mass-produced by industry, installed in their locations without special technical additions, and are easy to maintain.

The device, during the design and installation of which the specified requirements will be met, will eliminate the problem of objective control of dump truck loading and operational accounting of volumes of mined rock.

Literature review. The most accurate measurement of the dump truck load is provided by stationary scales [1], which are a weighing platform placed on a tensor sensor.

But it does not allow you to quickly control the weight of rock during its loading into the body of a dump truck, limit its movement speed, concentrate cargo flows, and has a high cost when applied to modern dump trucks with a large carrying capacity.

The on-board weighing system in real time provides information about the total weight of the cargo in the dump truck with its demonstration on the display screen [2]. Due to the fact that quarry multi-loading equipment is equipped with hydraulic suspension, hydraulic sensors are used in this system, the operation of which is based on the measurement of lubricant pressure. However, the system under consideration also does not provide control of the excavator driver over the process of loading the vehicle. In addition, hydraulic sensors are susceptible to technical deviations over time and are difficult to install and maintain.

The device for dimensional and weight control of cargo weight of the VEDA firm [1] is based on the use of tensor sensors TSWA-1, the nominal mass (MAX) for which is 1; 2; 3; 4; 7.5 and 10 tons. At the same time, the permissible overload from the nominal is 125 %, and the destructive load are (MAX)

≥ 150 %. Therefore, this device cannot be used for multi-load dump trucks transporting rock.

A device for dimensional and weight control of a car has been developed at the Department of Electronics and Computer Engineering of Sumy State University [3]. It performs the following functions:

- determination of cargo mass;
- comparison with the maximum permissible mass;
- outputting data on the display.

This device is based on four tensor sensors with a maximum load on the car of 20 tons according to the initial data of the project. Therefore, it is also unsuitable for modern multi-load dump trucks.

Unsolved aspects of the problem. The development of the device for operational control of the loading of multi-cargo dump trucks largely depends on the design features. This determines the importance of using such sensors of primary information, which are serially manufactured in industry, easily mounted in measuring cities, reliable in operation and react with sufficient accuracy to the change of mass in the body of the dump truck. Due to the fact that the sensors also react to the change of pneumatic cylinders of the dump truck, its non-horizontal installation during loading, contamination of the body, etc., it is necessary to create a mathematical block capable of calculating the rock net mass loaded during its excavation cycle [3, 4]. This information must be displayed both in the driver of the dump truck and in the excavator machine that performs its loading.

Purpose of the article. To substantiate and develop an algorithm for the operation of the device for operational control of the loading of a dump truck in a quarry, to carry out the appropriate mathematical calculation, to draw up its functional and principle electrical circuit and to select the necessary electronic database. To investigate the features of known sensors used in weighing systems and take into account the conditions of their operation on multi-load dump trucks as much as possible and choose the most suitable. To provide the ability to quickly control the mass of rock in the body of the dump truck after each unloading of the excavator bucket by both the driver and the excavator operator.

Materials and methods. Review of materials and research of devices that carry out on-board weighing of wagon loads, assessment of their technical and operational characteristics. Analysis of the known methods for converting cargo weight into an electrical analogue, substantiation of the effectiveness of the chosen one and recommendation of a technical means that makes certain this [3]. Detailed review of the suspension of automatic load-haul-dump vehicles. Finding a rational location of the sensor on the dump truck and determining the method of its attachment.

Development of a mathematical block for determining the net mass of rock loaded into the body of a dump truck, drawing up a functional and basic electrical circuit of the device, checking it on a test sample.

Presentation of the main research and explanation of scientific results. Operational control of loading the dump truck with rock during its excavation is expedient to be carried out according to the following algorithm:

- conversion of cargo mass into an electrical signal;
- primary processing of this signal;
- calculation of the total net mass of rock that loaded after each cycle of its excavation;
- displaying data to the dump truck driver and transferring them to the excavator driver.

According to this algorithm, the functional scheme of the device is compiled (Fig. 1).

This scheme works in the following way. Counting pulses from the output of the pulse generator *1* are sent to the pulse counter *2* through the matching circuit *3*. The enable or disable pulse for this scheme comes from the output of the comparison element *4*, which compares the output voltage of the digital-to-analog converter *5* and the math unit *6*.

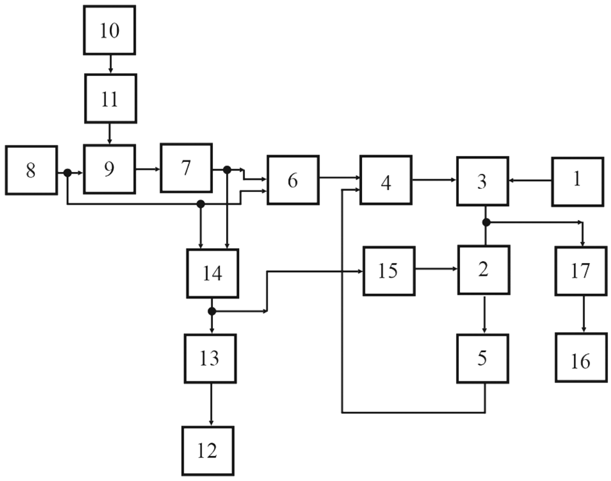

Fig. 1. Functional scheme of the device for operational monitoring of the nominal dump truck load

The function *4* is that this element prohibits the arrival of pulses through circuit *3* if the output voltage *6* is less than the output voltage *5*. Unit *6* is designed for analog subtraction of the voltage that comes from the output of the analog memory unit *7*, from the voltage that comes from the output of the analog memory unit *7*, from the voltage that comes from the output of the weight sensors *8*. Input *7* is connected to output *8* through hermetic contact *9* only during the movement of the dump truck. It is controlled *9* by the voltage coming from the tachogenerator *10*; the control signal is generated by block *11*.

When the dump truck stops, block *9* disconnects the input of block *7* from signals coming from weight sensors *8*. Analog memory block *7* remembers the signal level that was last before stopping. Mathematical unit *6* performs its subtraction from the signal generated by weight sensors *8*, so the output of unit *6* will have a zero voltage level after stopping the dump truck. Due to this, the influence of the dump truck's tare, the initial pressure in its pneumatic cylinders, as well as excluded errors due to possible unevenness of the work site.

Thus, the device as a whole is prepared for processing signals functionally dependent only on the weight of the cargo in the body of the dump truck. When loading the dump truck, the output voltage of block *6* will increase from the obtained zero level. Since the signal level at the output of block *5* is also zero at this time, block *4* will allow the arrival of pulses to counter *2* through the coincidence circuit *3*. The output voltage of block *5* will increase as the number of pulses registered by the counter increases. When it exceeds the voltage at the output of block *6*, comparison element *4* will prohibit the further arrival of pulses to the counter.

Thus, the counter panel will display a number proportional to the voltage level at the output of unit *6*, that is, the output voltage of the weight sensors *8*, which functionally reflects the weight of the load in the body of the dump truck at this time.

A pulse counter *12*, as well as a control key *13*, a second comparison element *14* and an information reset key *15* are used to count loading flights. Its algorithm is built in such a way that in order to enter one flight on the counter, the following conditions must be fulfilled in sequence:

- the dump truck must be loaded;
- the dump truck must first move and then stop;
- the dump truck must unload;
- the dump truck must move from its place.

The calculation of visits will not be carried out if any of the specified conditions are excluded, or if their sequence is changed. The total display of the mass of transposed loads is planned to be performed on this excavator using counter *16*. It counts the pulses that may come through the low-frequency inductive link channel or by other means. Resetting information is performed with key *17*.

When implementing this functional scheme during the development of a device for operational control of the load of a dump truck, special requirements are placed on weight sensors (unit *8*) that convert the mass of suspended rock into its electrical counterpart [5, 6]. Of course, the accuracy of weighing primarily depends on the perfection of these sensors and the technology of their application. Tensor transducers, magnetoelastic, magneto-anisotropic transducers, inductive, transformer rheostat and other sensors are used according to the operating conditions and the requirements. All of them represent changes in the state of the sensitive element under the influence of the mass of the cargo, followed by the reproduction of this indicator in electrical form. A change in the state of a sensitive element can occur in the form of its movement or the occurrence of elastic deformations of stretching, compression, bending and twisting in a simple or complex form. At the same time, in order to reproduce its characteristics with the necessary accuracy, the sensitive element must have linearity and not change it under the influence of external factors. In addition to the above, additional problems arise when creating electronic scales mounted in a dump truck.

The sensitive element must have a high resolution to withstand frequent shock overloads, maintain stable characteristics under the influence of temperature and other adverse factors. In addition, when installing a sensitive element, structural changes to the components and systems of the dump truck are unacceptable, and the element itself, at the same time, must be either easy to manufacture, or, even better, mass-produced.

When loading a dump truck, different types of elastic deformations occur in various elements of its construction, but it is not entirely appropriate to use them as a source of information about the weight of the load. This is explained by the fact that, firstly, the load on the platform is unevenly distributed, and secondly, its impact on the structural elements is not always the same.

The strain transducers used to sense these strains have very small output values, commensurate with their temperature coefficient of resistance, and require careful adjustment and balancing before each measurement.

Magneto-elastic and magneto-anisotropic converters, in addition to the mentioned disadvantages, may not reproduce and linearize the characteristics [7, 8]. In addition, when using these converters, it is necessary to conduct time-consuming research to find the most suitable places for their installation.

Inductive, transformer rheostat and other displacement sensors have the following disadvantages to a lesser extent, so they are more acceptable, but in this case converters of the mass of the load into the proportional displacement value are required. At the same time, changes in the deformation of the membrane or spiral tube of the sensor under the influence of the load on the platform of the dump truck lead to the movement of the sliding rheostat, which determines its total resistance in proportion to the given load. The movement of the membrane or tube should occur only within the limits of elastic deformations to reproduce the characteristics and reliable operation of such transducers.

If the converter functions by measuring the pressure of the gas formed in the cylinder within the nominal load, then when the dump truck moves on quarry roads, overloads occur, causing inelastic deformations of elastic elements. Therefore, their reliability may decrease; in addition, the moving contact of the rheostat of any sensor installed on the autorestarter is one of the weak points of measuring devices. If the converter is designed to measure maximum (peak) loads, then the level of the useful output signal will be lower and it must be amplified, which will have a large impact on various types of errors. The disadvantage of non-contact transducers (such as inductive, capacitive, piezoelectric, etc.) is that they require a special voltage source for power, and the level of the useful signal in most cases is insufficient for further processing [9, 10].

When using these sensors to measure pressure in pneumatic cylinders, there is an additional problem of their number, since it is desirable to take into account pressure changes in the upper and lower cavities of each cylinder. The use of a large number of pressure sensors makes it necessary to average the received signals, which, with the nonlinearity of the characteristics of the pneumatic elements of this type, significantly complicates the electrical circuit of the device and, as a rule, reduces its accuracy, reliability and cost.

Contactless inductive and transformer converters of linear and angular movements that allow measuring the movement of the sprung part of the dump truck relative to the non-sprung part are practically devoid of the mentioned shortcomings. A possible increase in the accuracy of measurements is due to the absence of an intermediate element of the pressure-strain transducer of the membrane or spiral tube [11, 12]. When using these transducers, the movement of the pneumatic element (pneumo-hydraulic cylinder piston) is measured directly during gas compression under the action of the load. The transducer is not subjected to any load; it only reproduces the measured displacement in electrical form. The level of the output signal can be sufficient (determined by the design), since the dimensions of the sensor are practically not limited by anything, and the summation of the signals is carried out by sequentially turning on the output windings [13, 14]. Only four transducers need to be installed for measurements, regardless of the number of cylinders and the type of suspension. Since the summation and averaging of cylinder parameters on each support is carried out by their parallel installation, i.e. construction. The given arguments indicate that when choosing primary transducers, it is most expedient to provide for the use of non-contact sensors of linear or angular movement of spring-loaded parts of the dump truck relative to non-spring-loaded parts depending on load changes.

Linear displacement sensors allow you to get the required accuracy, but they must be manufactured according to the requirements and consist of special assemblies that are welded to the sprung and non-sprung parts of the dump truck.

Places suitable for this, protected from possible mechanical damage, especially on the rear suspension, are difficult to find.

It is more appropriate to consider the use of sensors of angular movements. Long rods, sensing the load, reproduce the corresponding movements of the cylinder pistons in angular terms. That is, the relationship between the movement of the piston n and the angle of rod inclination α relative to the plane of the frame or platform at the rod length l has a simple form: $n = l \cdot \sin\alpha$.

So, in this case, it is advisable to use any known electric micro-machine, the output voltage of which, depending on the angle of rotation of its rotor, is described by this function. The drive of such a rotor should be the longitudinal rod of the dump truck, which will ensure the linearity of the output signal when the angular movement of the rod changes.

The characteristics of such a micro-machine fully correspond to the selsyn (self-synchronizing) included in the transformer mode. It is known that its output voltage u also has a sinusoidal dependence on the angle of rotation of the rotor α at a given voltage of the power source : Therefore, in the developed device for operational control of the dump truck load and as sensors of primary information, it is advisable to use selsyns, the scheme of which is shown in Fig. 2.

The alternating voltage required to power the selsyn stator windings comes from the pulse generator. These windings are connected in parallel and the rotary windings are connected in series so that the output voltage of all sensors is summed.

After rectification (diodes D_1–D_4) and smoothing of ripples (capacitor C_1), this voltage enters the input of the device.

It is rational that the use of selsyn as a displacement conversion sensor solves the issue of its installation on a dump truck (no costs for the manufacture of fastening elements are required). These fastening elements are manufactured by the

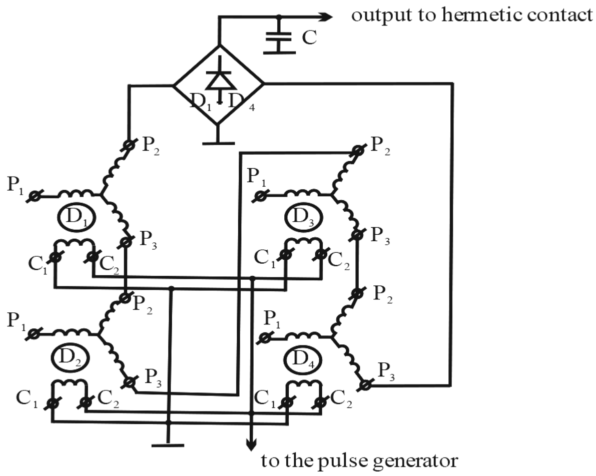

Fig. 2. Scheme of selsyns inclusion

industry in series of various types, accuracy classes and designs. In addition, there is no need to develop a summation unit, and the power of the output signals is usually sufficient for further processing by electronics even in small-sized and, accordingly, low-power self-synchronizing.

The schematic electrical diagram of the weighing device is shown in Fig. 3.

The main element of the analog memory block is capacitor C_1 that is connected to an amplifier with a high-impedance input. Since the resistance of the charged capacitor, which is used as a signal source, is very large, to match it with the load resistance, an analogue of the emitter follower on the operational amplifier is used OA_1.

For an even greater increase in the input resistance of the linear potential switch, an emitter repeater is additionally included KP_1. The input resistance of such a device is several tens of MΩ with a transmission factor of almost unity. To exclude the additional discharge circuit of the capacitor C_1 through the source of signal memorization, the output of this source contains a hermetic magnetically controlled contact K, which turns off the signal source during memorization.

The output voltage OV_1 through the resistor R_5 is fed to the inverting input of the operational amplifier OV_2, which carries out the algebraic addition of this signal with the signal coming from the weight sensor through the resistor R_1 to its non-inverting input. The difference signal from the OV_2 output through the filter R_{11}, C_6, R_{12} is fed to the OV_3 amplifier, which performs the functions as a zero-device. A controllable pulse generator is assembled on the four inverters of the MC, in which the resistor R_{18} and the capacitor C_8 determine the frequency of their passage. At the same time, two valves are used for the generator circuit and two for controlling its operation. When a high allowable potential is received from the valve MC, the generator is excited and pulses are sent to the counter through the valve MC_2, if there is a high potential at the input *12* of this valve.

At the same time, the pulses also enter the input of the integrating device (C_9, KT_2, OV_4), made according to the same scheme as the analog memory block, but the integrating capacitor C_9 is included in the negative feedback circuit. Negative feedback is also applied through resistor R_{19} and to non-inverting input *8*. This integrator has high input impedance, as well as a long integrated level retention time. Its output voltage, which is increasing in proportion to the number of pulses arriving at the input, is also applied to the non-inverting input of the zero-device through the filter R_{13}, C_7, R_{14}. As soon as the level of this voltage equals the level of the voltage coming from the mathematical block, the zero-device through the valve MC will prohibit further operation of the pulse generator and their arrival at the counter and the input of the integrator. Protective diodes D_1 and D_2 are used so that the valve MC does not receive a negative potential. Thus, the counter will receive the number of pulses that is proportional to the voltage level at the output of the mathematical block.

The output voltage level of the integrator may drop to an unacceptable limit with long-term loading (preparation for rock slaughter, scrapping of low-quality pieces, etc.). This happens because the leakage current of the capacitor here is greater than in the analog memory unit, and its capacity is much smaller. It is necessary to periodically control the border and restore it with non-informative impulses to prevent such a phenomenon. It is done in this way. Non-informative pulses are received at the input of the integrator in the same way as informational ones, but pulses will be received at the counter only if the trigger ($1MC_2$, $2MC_2$) is in such a state that a high potential will be present at the output of $2MC_2$. It is set to this state by the differential unit every time there is a change in the signal limit at the sensor output. The differential unit (OV_5) acts as a Schmitt trigger which is shifted to the positive region of the output voltage through the resistor R_{22} on the non-inverting input. Differentiation is carried out using a chain ($R_{21}C_{11}$). Transfer of $2MC_2$ to a single state occurs simultaneously with an increase in the voltage level at the output of OV_2

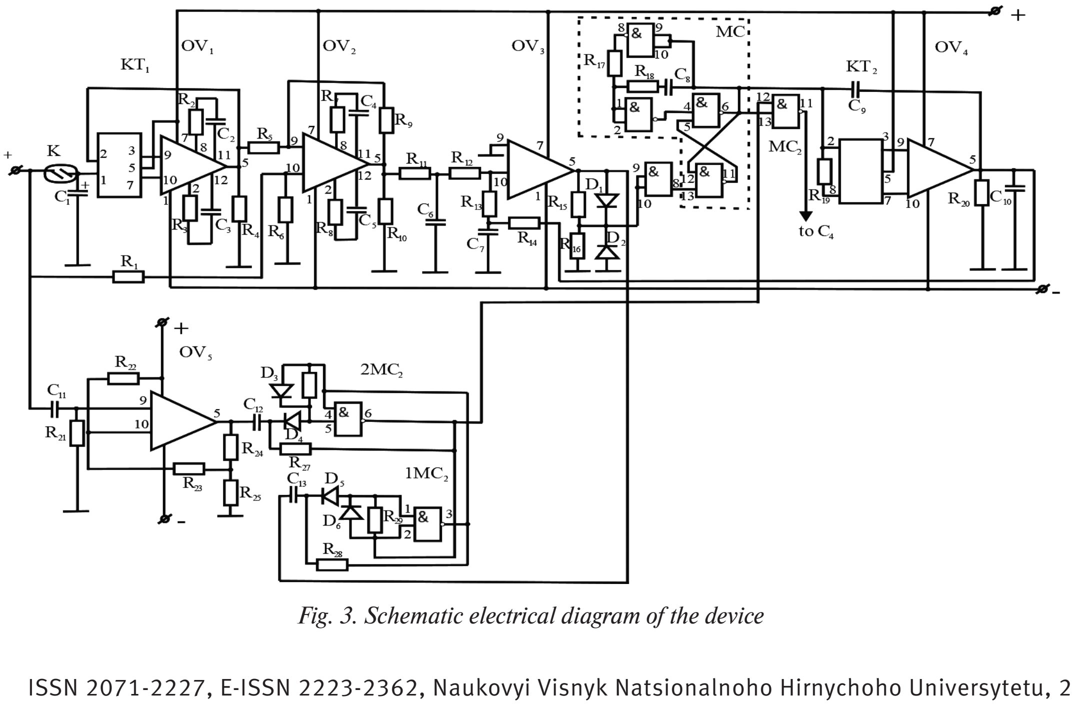

Fig. 3. Schematic electrical diagram of the device

and, accordingly, with the switching of OV_3 to the state in which the generator is excited. This is how information pulses are generated.

After the end of the integration process and when comparing the voltages at the input of the zero device, the latter switches the trigger to the zero state. "Recharging" of the integrator may be necessary at any time and in the intervals between load cycles. At the same time, the zero-device allows the operation of the pulse generator, and the trigger remains in the zero state and the "recharge" pulses do not reach the counter.

The device, which is assembled according to the scheme presented, demonstrated clear operation and compatibility of all nodes. But in order to restore the output voltage level of the integrator between cycles to the sensitivity limits of the null device, it is necessary that several hundred pulses arrive at its input. Such a scheme can introduce an additional error to the device as a whole, especially when the pulse generator is turned on at the same time based on the signal of the changed level of the sensor's output voltage and the integrator's output voltage signal. The pulses necessary to restore the output level of the integrator are also received at the input of the information pulse counter and summed with them. Therefore, the integrator circuit is replaced by a bit-by-bit weighted summation of the currents of weight resistors that are turned on by transistor switches and, in turn, are controlled by counter triggers. This counter works in code 8; 4; 2; 1 that is achieved by separate control of the fourth trigger, as well as inverse communication from its output (single output) to the second. The decoder is binary-five. The first trigger switches the keys of even or odd numbers; the other triggers switch the corresponding pair of keys. The scheme of the digital-to-analog converter is shown in Fig. 4.

The corresponding weighted resistor is connected to the power bus or to the common zero bus. It depends on the code installed on the counter.

The counter code and the corresponding weighted actual current summation are given in Table 1. The output voltage of the digital-to-analog converter increases linearly and stepwise from the zero level to the maximum when pulses from one to ten are received at the input of the counter (Table 1).

The "weight" of each step is determined by the level that provides the current flowing through the resistor R_V. The output voltage level of this digital-to-analog converter is constant while maintaining the state of the counter.

The developed device uses three such decades, which allow indexing tens, units and tenths of a ton of weighed rock.

Industrial tests of the device were carried out in the conditions of the Poltava Mining and Crushing and Beneficiation Plant, which develops an iron ore deposit using an open method. An experimental sample of the device was installed on a BelAZ-540 dump truck, the load of its rock was carried out by an EKG-4.6 excavator in characteristic sections of the quarry, where its granulometric composition was statistically different. According to the technical solution of the device, the registration of information about the weight of the loaded rock took place in parallel on the dump truck and the excavator.

Table 1

The counter code and the corresponding weighted currents summation

No. of impulses	Position of the triggers				Weighted resistors			
	Tg 1	Tg 2	Tg 3	Tg 4	8	4	2	1
0	0	0	0	0	–	–	–	–
1	1	0	0	0	×	–	–	–
2	0	1	0	0	–	×	–	–
3	1	1	0	0	×	×	–	–
4	0	0	1	0	–	–	×	–
5	1	0	1	0	×	–	×	–
6	0	1	1	0	–	×	×	–
7	1	1	1	0	×	×	×	–
8	0	0	0	1	–	–	–	×
9	1	0	0	1	×	–	–	×

In order to compare the results and assess their accuracy, this load was simultaneously weighed using a DVZ-2 spring-type weight sensor.

This sensor was installed on the lifting rope of the excavator boom, so it recorded its deformation, which occurred depending on the weight of the rock loaded into the bucket of this excavator. According to the specified changes, electrical signals were formed in the rope, based on which statistical processing of the sensor taring schedule was carried out (Fig. 5).

Based on these curves and the indicators of the weight sensor, registered on the jump chart of the multi-channel recorder H320, the mass of the rock loaded into the bucket of the excavator and the final mass into the body of the dump truck were determined.

The granulometric composition of the rock was estimated by the linear size of the predominant piece (x_{max}) and its quantity (y_{max}) in the volume of the excavator's stope, the latter characteristics are easily determined in industrial conditions, but in scientific and technical calculations, the diameter of the average piece (d_{av}) is usually used. The values of the (d_{av}) are calculated according to the formula

$$d_{av} = \frac{e \cdot y_{\max} \cdot x_{\max}^2}{\Delta n} \Gamma\left(\frac{n+2}{n}\right),$$

where Δ is the interval between adjacent values of the size of the pieces; n is the normalizing multiplier; $\Gamma\left(\frac{n+2}{n}\right)$ is the gamma function [3]. The values x_{max}, y_{max} is determined based on statistical processing of photographs of rock collapse in the process of its excavation. All data obtained when weighing the

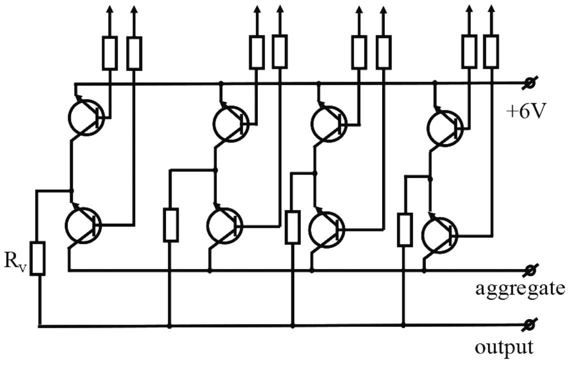

Fig. 4. Digital-to-analog converter scheme

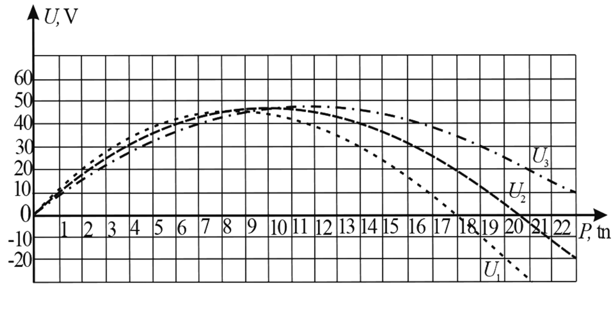

Fig. 5. Taring schedule of the DVR-2 weight sensor:

U1, U2, U3 – output voltage when the load increases for ropes with a diameter of 31, 25 and 28 mm, respectively

Table 2

Comparative data of rock weighing with the proposed device and with the use of the DVR-2 weight sensor

Intervals d_{av}, m	Number of measurements (sample size)	Average values of the rock mass in the body of the dump truck, t		Relative error $\frac{\lvert P_1 - P_2 \rvert}{P_2}$, %
		P_1	P_2	
0.1–0.2	12	25.7	26.8	4.1
0.2–0.3	23	25.4	26.6	4.5
0.3–0.4	29	26.9	25.8	4.3
0.4–0.5	14	26.8	25.6	4.7
Over 0.5	8	25.3	26.7	5.2

rock were grouped according to the following intervals: 0.1–0.2; 0.2–0.3; 0.3–0.4; 0.4–0.5; more than 0.5 m, for each of them the average indicators of the weight of the cargo and measurement errors were determined. The obtained results are presented in Table 2.

The results of rock weighing with the proposed device are slightly different from the results obtained with the DVR-2 sensor, which is officially approved for weighing lifting loads (Table 2).

But it is almost impossible to constantly use the DVR-2 sensor on an excavator when it performs a large number of cycles in a shift period, and it is also very difficult to get the final information.

The proposed device performed reliably during all tests.

Conclusions.

1. It has been proven that it is advisable to determine the function of converting the weight of the dump truck into an electric analogue based on the set of angular movements of its longitudinal rods, which reproduce the linear movements of the pistons of hydraulic cylinders. Therefore, sensors included in the transformer mode are used as primary information sensors. They are made of various classes of accuracy and design features, are not demanding in maintenance and do not require special difficulties during installation.

2. A mathematical block for determining the net-mass of rock loaded into the body of a dump truck for each cycle of its excavation has been developed.

3. The dump truck load control algorithm was formulated and the functional scheme of the device was drawn up based on it.

4. A basic electrical diagram of the device has been compiled, which provides for informing the driver of the dump truck and the driver of the backhoe-loader about the total mass of rock in its body after each unloading of the bucket of this excavator.

5. Industrial tests of an experimental sample of the device showed that it is able to quickly control the loading of a dump truck with an accuracy that is within the limits accepted for this type of work. During the testing period, primary information was steadily received, all units of the device functioned in a consistent and reliable manner. Installation of the device on a dump truck and an excavator did not require complex technical work.

6. The introduction of the device in quarries allows you to significantly improve the dispatching of freight and transport operations and optimize this important technological process.

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Упровадження математичної складової в розробці пристрою оперативного контролю навантаження автосамоскиду

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Мета. Створити пристрій зважування гірничої породи, навантаженої до кузову автосамоскиду, за кожним циклом її екскавації. Розробити математичний блок обчислення нетто-маси породи без урахування сторонніх факторів, що впливають на точність одержаного результату. Забезпечити оперативний контроль номінального навантаження автосамоскиду з боку водія і машиніста екскаватору.

Методика. Методологічною основою розв'язування поставленого завдання є комплексний підхід, що включає електронне моделювання технічних процесів, методи математичної статистики, аналіз результатів у математичному пакеті та їх прикладне застосування.

Результати. Складені функціональна та принципова електричні схеми пристрою зважування гірничої породи, навантаженої до кузову автосамоскиду, і передачі кінцевої інформації на даний екскаватор. Створено математичний блок пристрою, здатний запам'ятовувати сигнали, одержані з датчиків первинної інформації перед зважуванням, і віднімати їх від сигналів, одержаних із цих датчиків після кожного циклу зважування. Запропоновано в якості датчиків первинної інформації використовувати сельсини, включені у трансформаторному режимі, що серійно виготовлюються у промисловості, надійні в експлуатації й нескладні в обслуговуванні.

Наукова новизна. Запропонований пристрій виконано на рівні винаходу, його пріоритет визначений конструктивною розробкою та технічним рішенням. А саме, у пристрої установлений багатостабільний запам'ятовуючий трансформатор, до стираючої обмотки якого через підсилювач підключений тахогенератор, ланцюг послідовно підключених тригера, очікуючого мультивібратора та ключа, вихід якого з'єднаний із записуючою обмоткою багатостабільного запам'ятовуючого трансформатора, а також трансформатор, підключений до вхідної обмотки багатостабільного запам'ятовуючого трансформатора. Причому накопичувальний конденсатор з'єднаний з одним із входів ключа, а вхідні обмотки трансформатора з'єднані з датчиком ваги.

Практична значимість. Використання представленого пристрою дозволяє вести оперативний контроль номінального навантаження автосамоскиду, об'єктивний облік перевезеного вантажу й реалізованих трудовитрат, а також застосувати оптимальне обслуговування вантажно-транспортних робіт на кар'єрах. У майбутньому цей пристрій складе основу радіотелеметричної системи диспетчеризації роботи автосамоскидів.

Ключові слова: *автосамоскид, екскаватор, математичний блок, імпульси, напруга, датчики ваги, маса гірничі породи*

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